DECLARRATION

I, Mitsuru MAEDA, the translator of the attached document, do hereby certify that to the best of my knowledge and belief the attached document is a true English translation of Japanese Patent Application No. 2000-212512.

Signed, this nineteenth day of March, 2004

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[Name of document] Specification
[Title of the Invention] INFORMATION RECORDING APPARATUS, INFORMATION REPRODUCTION APPARATUS, AND INFORMATION RECORDING/REPRODUCTION APPARATUS

[Scope of Claims]

[Claim 1] An information recording apparatus which records a record mark in a phase change recording medium using a light spot to store information therein, characterized in that a position of a rear edge of the record mark is modulated in a main scanning direction of the light spot depending on the information to be recorded.

[Claim 2] The information recording apparatus according to Claim 1, wherein the light spot is formed by a laser beam, and wherein the modulation is performed by changing a power of the laser beam in two or more levels.

[Claim 3] The information recording apparatus according to Claim 1 or 2, wherein multi-valued information is stored using a unit including two or more of the record mark, and wherein the multi-valued information is represented by a combination of position information of each of the two or more of the record mark and the position information of the rear edge of each record mark.

[Claim 4] An information reproduction apparatus which reproduces the record mark according to a reference clock, said record mark being recorded in a phase change recording medium by the information recording apparatus according to Claims 1 to 3, wherein a time at which a clock used for detecting an edge of the record mark is emitted is different from a time at which another clock used for determining a strength of light reflected from the record mark is emitted.

[Claim 5] The information reproduction apparatus according to Claim 4, wherein a spot of light used for reproducing the record mark in the phase change recording medium according to the reference clock is less than that of the spot of the light used for recording the record mark.

[Claim 6] An information recording/reproduction apparatus comprising an information recording apparatus according to any one of Claims 1 to 3 and an information reproduction apparatus according to Claim 4 or 5.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

The present invention relates to an information recording apparatus, an information reproduction apparatus and an information recording/reproduction apparatus, in which information is optically recorded and/or reproduced. Particularly, the present invention relates to an information recording apparatus, an information reproduction apparatus and an information recording/reproduction apparatus, in which information is recorded in a rewritable recording medium having a recording layer including a phase change material at a high density utilizing multi-valued information recording and/or the information is reproduced.

[0002]

[Background Art]

As one of the optical recording media in which information is recorded and reproduced using a laser beam, a rewritable recording medium using a phase change material for the recording layer thereof is well known. This medium has a recording layer including a material which reversibly changes its phase between an amorphous phase and a crystalline phase upon irradiation of light thereto. Recording and erasure of information can be performed on the medium using a simple optical device. In addition, the medium has an advantage such that new information can be recorded in the medium while erasing the information previously recorded therein.

[0003]

In general phase change recording media, the information-recorded portion of their recording layer is in an amorphous state, and the non-recorded portion is in a crystalline state. When information is recorded, a laser beam on a recording power level irradiates the recording layer to heat the layer to a temperature not lower than the melting point of the recording layer, followed by rapid cooling, resulting in formation of a record mark achieving an amorphous

state. When information is erased, a laser beam on an erasure power level irradiates the recording layer to heat the layer to a temperature not lower than the crystallizing temperature of the recording layer, followed by gradual cooling, resulting in crystallization of the record mark in an amorphous state. The record mark is reproduced by detecting a change in the light quantity of the light reflected from the disc (recording medium), which is caused by the difference in reflectance between the amorphous portion and the crystalline portion or difference in phase between the light reflected from the amorphous portion and the light reflected from the crystalline portion.

[0004]

In the phase change recording methods, it is necessary to miniaturize the size of the record mark, but there is a limit to the mark size. Therefore, it is tried to perform multi-valued recording by including plural pieces of information in a record mark, in order to perform high density recording and high speed transferring. The multi-valued information recording methods are broadly classified into the following two types.

One of the methods is a method in which the area, shape or structure of record pits are changed so that the recording medium has multiple levels in average reflectance. Namely, in the method the multi-valued information can be recognized utilizing the change in the quantity of the reflected light.

The other is a method in which two dimensional information of record pits such as the shape, direction, position and arrangement of record pits are changed to form record pits with a plurality of combinations of such two dimensional information. For example, published unexamined Japanese Patent Applications Nos. 8-287468, and 11-25456 have disclosed a technique such that a unit including plural pits is formed while changing the number of the pits and arrangement of the pits to record multi-valued information.

[0005]

[Problems to be Solved by the Invention]

However, in the latter method in which a unit including plural pits is formed while changing the number of the pits and arrangement of the pits to record multi-valued information, the shape, size and position of the record pits have to be strictly controlled.

In addition, it is necessary for the method that the shape and size of record marks can be easily changed. In a phase change recording method in which record marks are formed in a heat mode, the shape of the record marks changes depending on the light quantity of the laser beam used for recording. Further, in a phase change recording method, it is difficult to form marks having a complex shape, and even if such marks are formed, it is difficult to reproduce the information of the record marks. When considering the recording accuracy and reproduction accuracy, the length of one unit has to be increased. Even when this method is used, satisfactory high density recording cannot be performed although a complex device has to be used for detecting the mark-arrangement information.

[0006]

Accordingly, the object of the present invention is to provide an information recording apparatus, an information reproduction apparatus, and an information recording/reproduction apparatus in which multi-valued information can be easily and stably recorded in a phase change recording medium and/or the recorded multi-valued information can be easily and stably reproduced.

[0007]

[Means for Solving the Problems]

The above-mentioned object can be attained by an information recording apparatus which records a record mark in a phase change recording medium using a light spot to store information therein and which is characterized in that a position of a rear edge of the record mark is modulated in a main scanning direction of the light spot depending on the information to be recorded.

According to Claim 2, the information recording apparatus is characterized in that the light spot is formed by a laser beam, and

the modulation is performed by changing a power of the laser beam into two or more levels.

[0008]

In the apparatus having such a constitution, for example, a recording power (Pw) in a range of from 8 to 15 mW on the surface of a disc is applied; a bottom power (Pb) in a range of 0 to 1 mW is applied; and an erasure power (Pe), which is changed in three levels in a range of 2 to 10 mW, is applied, as illustrated in FIG. 3. The mark has three types of shapes, i.e., a, b and c, depending on the levels of the erasure power. The lengths La, Lb and Lc of the recorded marks a, b and c are 0.1 μm, 0.15 μm and 0.2 μm, respectively. Thus, by changing the erasure power level, the length of the tail of the mark can be changed, resulting in change of the shape of the mark.

[0009]

According to Claim 3, the information recording apparatus recited in Claim 1 or 2 is characterized in that multi-valued information is stored using a unit including two or more of the record mark, wherein the multi-valued information is represented by a combination of position information of each of the two or more of the record mark and position information of the rear edge of each record mark.

[0010]

When the apparatus has such a constitution, sixteen-valued recording can be performed by changing the position and area of the mark as illustrated in FIGS. 4 and 5.

[0011]

According to Claim 4, when the information of the record mark which is formed in a phase change recording medium by the information recording apparatus recited in any one of Claims 1 to 3, is reproduced according to a reference clock, a time at which a clock used for detecting an edge of the record mark is emitted is differentiated from a time at which another clock used for determining a strength of light reflected from the record mark is emitted.

According to Claim 5, when the information of the record mark which is formed in a phase change recording medium by the information recording apparatus recited in any one of Claims 1 to 3, is reproduced according to a reference clock, a spot of the light used for reproducing the record mark in the phase change recording medium according to the reference clock is made to be less than that of the spot of the light used for recording the record mark.

[0012]

In this apparatus having such a constitution, as illustrated in FIG. 3, a reference clock 2031 is synchronized (2035) with a front edge when reproducing signals 2032 to 2034. Since the mark length is smaller than the diameter of the reproduction beam, the peak of strength of the reflected light shifts (2032, 2033 and 2034) in the scanning direction of the laser beam. As illustrated in FIG. 3, the signal strength is measured at a time (2036) 1 clock after the front edge. Thus, four levels (0, 1, 2 and 3) of reproduction signals can be recognized.

[0013]

According to Claim 6, the apparatus includes both an information recording apparatus according to any one of Claims 1 to 3 and an information reproduction apparatus according to Claim 4 or 5.

For example, an apparatus (information recording/reproduction apparatus KS) illustrated in FIG. 1, which has such a constitution as mentioned above, can perform recording and reproduction on a recording medium.

[0014]

[Description of the Preferred Embodiments]

The present invention will be explained referring to embodiments illustrated in figures.

(1) Abstract of the present invention

Prior to the explanation of embodiments, the abstract of the present invention will be explained.

In the present invention, the method for forming record marks

(i.e., the recording device configured to form record marks) in phase change recording and the method for reproducing the information of the record marks (i.e., the reproduction device configured to reproduce the information of the record marks) are improved.

FIG. 1 is a view illustrating the system configuration of an embodiment of the present invention. FIG. 2 is a schematic view illustrating marks recorded by a phase change recording method.

[0015]

As illustrated in FIG. 1, an information recording/reproduction apparatus KS, which is an embodiment of the present invention, includes a disc 10 which is a phase change recording medium, a recording unit 20 which operates during recording, a reproduction unit 30 which operates during reproduction, a beam diameter setting section 40 which sets the diameter of the light beam for recording and reproduction, and a driving section 50 which drives the disc 10 to rotate.

[0016]

The details of the disc 10 will be explained later.

The recording unit 20 includes a laser beam generator 21 configured to generate a laser beam, a power level changing device 22 configured to change the power level of the laser beam, and a multi-valued information setting device 23 configured to change the mark area to perform sixteen-valued information recording.

[0017]

The reproduction unit 30 includes a signal detector 31 configured to detect signals received from the disc 10 using light whose beam diameter is set by the beam diameter setting section 40 described later, a timing detector 32 configured to determine the signal detection period according to the reference clock, and a signal processor 33 configured to determine the level of strength of the reflected light from the record mark which is recorded in the disc 10 according to the signal sent from the timing detector 32.

The beam diameter setting section 40 sets the beam diameter of the laser beam for recording and the beam diameter of the laser beam

for reproduction. For example, the beam diameter of the reproduction laser beam is set so as to be smaller than that of the recording laser beam.

The driving section 50 drives the disc 10 to rotate, and informs the rotation number of the disc 10 to the timing detector32. Pre-pits are formed on the substrate of the disc 10. The reference clock is generated based on the pre-pit signal detected by the signal detector 31 and the rotation number of the disc.

[0018]

As illustrated in FIG. 2, a mark 101 recorded by a phase change recording method has a shape which is asymmetric in the laser beam scanning direction 102. Hereinafter, the front edge of the record mark in the laser beam scanning direction is referred to as a front edge 103 and rear edge of the record mark in the direction is referred to as a rear edge 104. The edges of the record mark have the following characteristics.

[0019]

The front edge is very sharp. Since the curvature (R) of the mark depends on the laser beam diameter, the shape of the front edge can be reproduced with good reproducibility. In addition, variation of the position of the front edge of record marks in the disc is little. In contrast, the rear edge is formed at a transition time of from the rapid cooling state to the gradual cooling state. Therefore, the shape and position of the rear edge easily change depending on the laser beam power.

[0020]

In the present invention, the information on the fluctuation of the rear edge is utilized for the multi-valued information recording. In a strategy such that the recording power level, bottom power level and erasure power level are changed, the position of the rear edge can be easily controlled by controlling the erasure power level, and thereby the mark length (L) can be controlled. Thus, by using such a simple method that the laser power is changed, the shape of the record

marks can be controlled, and thereby multi-valued information recording can be performed on a phase change recording medium (Claims 1 and 2)

By using this method, it becomes possible to perform multi-valued information recording in phase change recording (Claim 3).

In order to precisely read the marks having different shapes, it is necessary to improve the reproduction method. In general mark edge detection, the detection of the rear edge and the detection of the signal strength of the mark are performed at the same time. In contrast, in the present invention the time at which the edge is detected is prior to the time at which the signal strength of the mark is detected. Namely, the signal strength is detected at a time in which the signal strength decreases, i.e., at a time in which the signal strength largely changes depending on the area of the mark (Claim 4).

[0021]

In addition, it is possible to make the diameter of the reproduction laser beam smaller than that of the recording laser beam, to improve the detection sensitivity. For example, it is possible that recording is performed using red laser light having a wavelength of from 600 to 700 nm while reproduction is performed using blue laser light having a wavelength of about 400 nm. Alternatively, it is possible to perform reproduction using a lens with high NA, such as SIL (Solid Immersion Lens) (Claim 5). Further, it is possible to change the beam diameter by adjusting the focusing position of the laser beam using an optical system.

In addition, an information recording/reproduction apparatus having both an information recording device and an information reproduction device can be provided (Claim 6).

[0022]

(2) First embodiment (corresponding to Claims 1 and 2)

The recording medium for use in the embodiment will be explained. The substrate of the medium is made of polycarbonate, and the track pitch is 0.74 μm, which is the same as that of the DVDs (Digital

Versatile Discs). A recording layer including a phase change material is formed on the substrate.

FIG. 3 is a view for explaining the method (201) for changing the record laser pulse and the shape of the record marks formed by the laser pulse. The wavelength of the laser beam is 635 nm and the numerical aperture of the field lens is 0.6.

The record power (Pw) is 13 mW, and the bottom power (Pb) is 0.2 mW. The erasure power (Pe) is changed in three levels of 4 mW (2011), 6.5 mW (2012) and 7.8 mW (2013). The record mark has a shape among three shapes a, b and c depending on the erasure power. The lengths of the record marks in the laser beam scanning direction is 0.1 μm (La), 0.15 μm (Lb) and 0.20 μm (Lc), respectively. Thus, by decreasing the erase power level, the tail of the record mark is lengthened, and thereby the shape of the record mark can be changed.

[0023]

(3) Second embodiment (corresponding to Claims 4 and 5)

FIG. 3 is a view for explaining the method for reproducing the information of a record mark. The laser light for use in reproduction has a wavelength of 410 μm, and the numerical aperture of the field lens is 0.7. The power of the reproduction laser light is 0.6 mW.

[0024]

Numeral 2031 denotes a reference clock for use in signal detection, and numerals 2032 to 2034 denote reproduction signals of the marks a, b and c. The reference clock is synchronized (2035) with the front edge when reproducing signals. In order to explain this situation, the reproduction signals are illustrated in FIG. 3 while being overlapped. Since the mark length is smaller than the diameter of the reproduction beam, the peak of reproduction signals shifts on the order of a, b and c. As illustrated in FIG. 3, the signal strength is measured at a time (2036) 1 clock after the front edge. Thus, four levels (0, 1, 2 and 3) of the reproduction signals can be recognized. Since the peak of the reproduction signals shifts in order of a, b and c, it is preferable to detect the signal at the position illustrated

in FIG. 3 because the difference in signal strength can be increased, resulting in improvement in recognition of the record marks.

[0025]

(4) Third embodiment (corresponding to Claim 3)

The mark position and the multi-valued information recording method utilizing mark area modulation will be explained referring to FIG. 4. Numerals 301, 302 and 303 denote record marks, reference clocks and reproduced waveforms, respectively.

The substrate of the medium is made of polycarbonate. The track pitch is 0.74 μm which is the same as that of DVDs. A recording layer including a phase change material is formed on the substrate.

The record laser beam has a wavelength of 635 nm, and the numerical aperture of the field lens is 0.6. The wavelength of the reproduction laser beam is 410 nm and the numerical aperture of the field lens is 0.7.

[0026]

The record power, bottom power, erasure power and reproduction power are 13 mW, 0.2 mW, from 4 to 7.8 mW, and 0.6 mW, respectively.

The frequency of the clock is 26.2 MHz and Tw is 0.133 μm. Marks are recorded at a pitch of 0.133 μm such that the front edge is synchronized with a clock. The pitch between units is 0.52 μm.

[0027]

In a unit (3011), one to three marks (3012) are recorded. The recording method is the same as that in the first embodiment. Namely, the length (L) of the marks is changed in three levels, 0.1, 0.15 and 0.20 μm. The mark pitch is 0.13 μm, and the length of the longest mark is 0.20 μm. There is a case where the recorded marks interfere with the adjacent marks depending on the configuration of the three marks. However, even if interference is caused, sixteen types of reproduction signal waves can be formed by the unit. Therefore, there is no problem even if interference is caused.

[0028]

FIG. 5 illustrates sixteen different combinations obtained by

combining the mark configuration (a, b and c) with the levels (0, 1, 2 and 3) of strength of the reproduction signal which are obtained by changing the number of marks, and the area (i.e., the length) of each mark. In a unit, by combining the front two bits (00, 10, 01 and 11) with the rear two bits, sixteen different 4-bit data can be produced. For example, "a/1" means that a mark on level 1 is present at a position (a) in the waveform 303 in FIG. 4. The user data are divided by every 4 bits and the data are recorded in each unit. Reproduction is performed in the same way as that in the second embodiment.

By using this method, sixteen different combinations of 4-bit data can be recorded in a unit.

[0029]

As can be understood from the above description, the present invention produces the following effects.

Effect of the apparatus of Claims 1 and 2

The mark size can be changed by changing the laser power. The mark length can be changed with only one pulse. Therefore, a simple driver can be used for laser driving.

Effect of the apparatus of Claim 3

The track pitch and line density of current DVDs is 0.74 μm, and 0.27 μm/bit, respectively. The recording medium described in the third embodiment has a track pitch of 0.74 μm which is the same as that of DVDs. In addition, by performing sixteen-valued information recording, 4-bit data can be recorded in a unit which is present at a pitch of 0.52 μm. Therefore, the line density of the medium is 0.13 μm/bit (0.52 μm/4 bits). Namely, the medium has a capacity about twice that of DVDs.

By using the apparatus according to Claim 4, the precision in detecting a small mark can be improved. By using the apparatus according to Claim 5, the precision in detecting a small mark can be improved. In addition, according to Claim 6, the information recording apparatus and information reproduction apparatus of the

present invention can be incorporated in an information recording/reproduction apparatus.

[Brief Description of Drawings]

[Fig.1]

A diagram illustrating the system configuration of the embodiments of the present invention.

[Fig.2]

A schematic diagram illustrating marks recorded by phase change recording in the embodiments of the present invention.

[Fig.3]

A diagram for explaining the method for changing the record laser pulse in the embodiments, and for explaining the shape of the marks recorded by the pulse.

[Fig.4]

A diagram for explaining the sixteen-valued information recording method used for the embodiments.

[Fig.5]

A diagram illustrating data obtained by combining the mark position with the levels of strength of the reproduction signal which are obtained by changing the number of marks and the area of each mark.

[Reference Numerals]

KS: information recording/reproduction apparatus
Pw: record power
Pb: bottom power
Pe: erasure power
10: disc
20: recording unit
21: laser beam generator
22: power level changing device
23: multi-valued information setting device
30: reproduction unit
31: signal detector
32: timing detector

33: signal processor

40: beam diameter setting section

50: driving section

101: record mark

102: beam scanning direction

103: front edge

104: rear edge

201: record laser pulse changing method

202: marks recorded by laser pulses

203: reproduction method

301: record mark

302: reference clock

303: reproduced waveforms

2011-2013: levels of erasure power

2031: reference clock for signal detection

2032-2034: reproduced signals

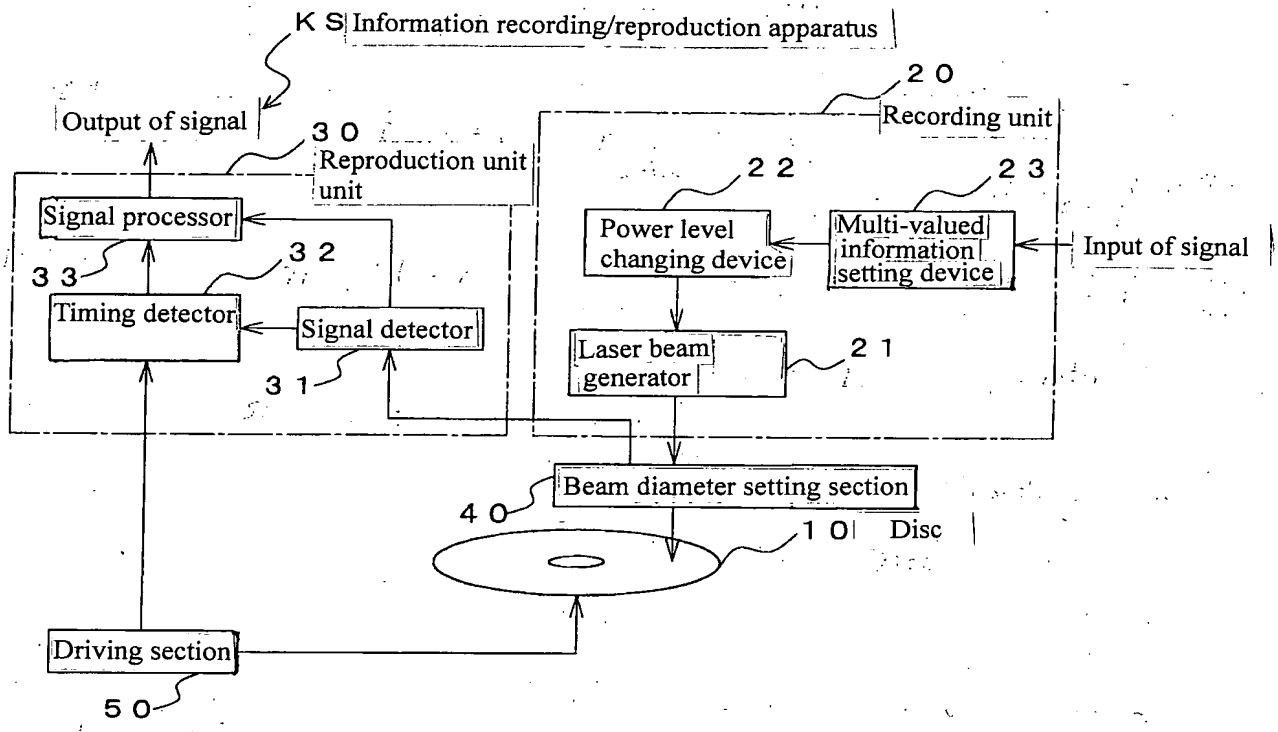
2035, 2036: reference clock timing

3011: unit

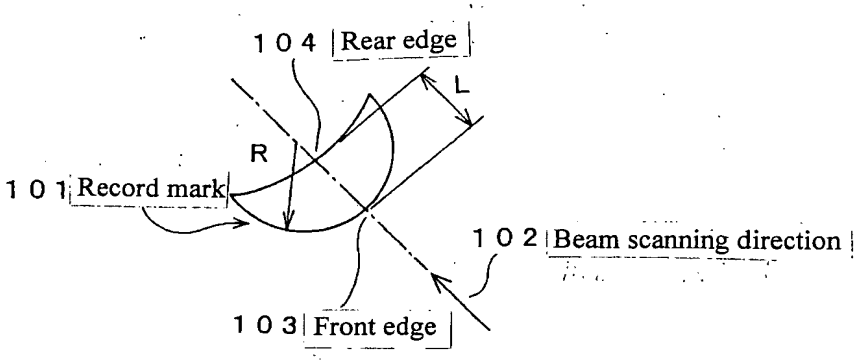
3012: record mark

[Name of Document] Drawings

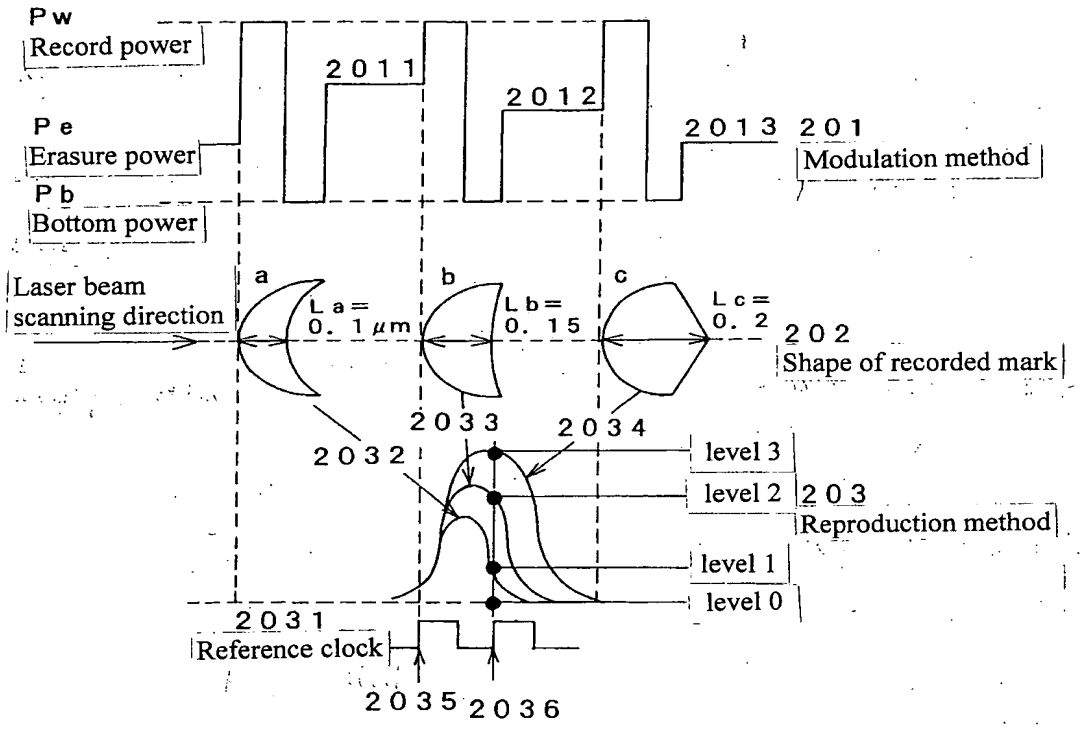
[FIG. 1]



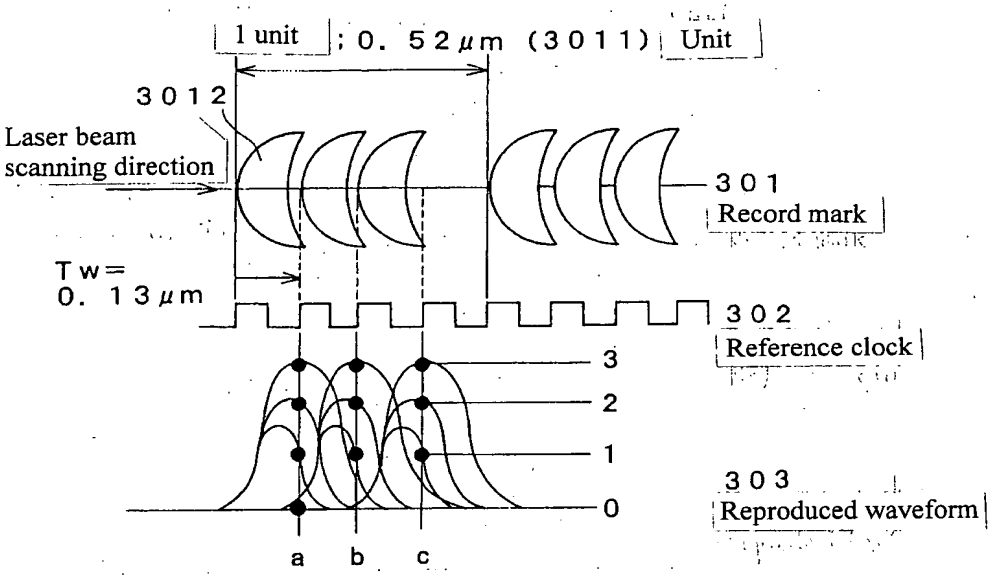
[FIG. 2]


104 Rear edge
L
R
101 Record mark
102 Beam scanning direction
103 Front edge

[FIG. 3]


Pw
Record power
2011
2012
Pe
Erasure power
2013 201
Modulation method
Pb
Bottom power
Laser beam
scanning direction
a
La=
0.1μm
b
Lb=
0.15
c
Lc=
0.2
202
Shape of recorded mark
2033
2034
2032
level 3
level 2
203
Reproduction method
level 1
level 0
2031
Reference clock
2035
2036

[FIG. 4]



[FIG. 5]

		Front two bits			
Rear two bits		00	10	01	11
	00	no mark	a / 1	a / 2	a / 3
	10	a, b / 1	b / 1	b / 2	b / 3
	01	b, c / 1	c / 1	c / 2	c / 3
	11	a, b, c / 1	a, c / 1	a, c / 2	a, c / 3

[Name of Document] Abstract of the Disclosure

[Abstract]

[Object of the Invention] To provide an information recording apparatus, etc., which can easily and stably record multi-valued information in a phase change recording medium and easily and stably reproduce the information.

[Solutions] An information recording apparatus which records a record mark in a phase change recording medium using a light spot to store information therein and which is characterized in that a position of a rear edge of the record mark is modulated in a main scanning direction of the light spot depending on the information to be recorded. The light spot is formed by a laser beam, and the modulation is performed by changing the laser power in two or more levels. Multi-valued information is stored using a unit including two or more of the record mark. The multi-valued information is represented by combining the position information of each record mark and the position information of the rear edge of each record mark.

[Selected Drawing] FIG. 3